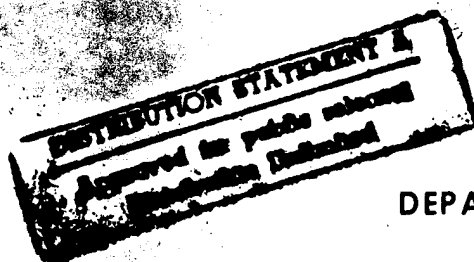


*TRACKING AIR FORCE PALLETS USING RFID TECHNOLOGY:  
A CONCEPT STUDY*

THESIS

Gary A. Gross, B.S.  
Captain, USAF

AFTT/GLM/LAL/95S-6



DTIC QUALITY INSPECTED 8

DEPARTMENT OF THE AIR FORCE  
AIR UNIVERSITY  
**AIR FORCE INSTITUTE OF TECHNOLOGY**

Wright-Patterson Air Force Base, Ohio

AFIT/GLM/LAL/95S-6

*TRACKING AIR FORCE PALLETS USING RFID TECHNOLOGY:  
A CONCEPT STUDY*

THESIS

Gary A. Gross, B.S.  
Captain, USAF

AFIT/GLM/LAL/95S-6

19951102 091

Approved for public release; distribution unlimited

The views expressed in this thesis are those of the author  
and do not reflect the official policy or position of the  
Department of Defense or the U.S. Government.

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

***TRACKING AIR FORCE PALLETS USING RFID TECHNOLOGY:  
A CONCEPT STUDY***

THESIS

Presented to the Faculty of the Graduate School of Logistics  
and Acquisition Management of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the  
Requirements for the Degree of  
Master of Science in Logistics Management

Gary A. Gross, B.S.  
Captain, USAF

September 1995

Approved for public release; distribution unlimited

## **Acknowledgments**

Several individuals provided me with a great deal of help and encouragement throughout this research effort. I am deeply indebted to Mark Reboulet and Lisa Wagner of the AFMC Automated Information Technology Program Management Office for their support and assistance throughout this study. Rand Brown and Jerry Landt of the Amtech Corporation provided a wealth of information, as did Paul Estey of the Volpe National Transportation Systems Center and Ricky Morton of Headquarters United States Marine Corps. I would like to express my sincere gratitude to my thesis advisors, Dr. William Cunningham and Dr. Kirk Vaughan, for their support and assistance in times of need. Finally, I especially want to thank Kelly West and Ronnie Gross for their love, understanding, and support during the entire research process.

Gary Gross

## Table of Contents

	Page
Acknowledgments .....	ii
List of Tables.....	vi
Abstract.....	vii
I. INTRODUCTION .....	1-1
Chapter Overview .....	1-1
General Issue.....	1-1
Problem Statement .....	1-2
Research Objective.....	1-2
Investigative Questions.....	1-3
Scope.....	1-3
Issues .....	1-4
Chapter Summary.....	1-5
II. LITERATURE REVIEW .....	2-1
Chapter Overview .....	2-1
Recurring Problems.....	2-2
Materiel Costs.....	2-4
Visibility Issues .....	2-5
Human Factors.....	2-5
Operational Considerations .....	2-6
Available Technology.....	2-8
Commercial Transportation Practices .....	2-10
Air Cargo.....	2-12
Scheduled Airlines.....	2-13
Surface Freight.....	2-13
Air Mobility Command Aerial Ports .....	2-14

	Page
Systemic Visibility Initiatives .....	2-15
Chapter Summary.....	2-16
III. RESEARCH METHODOLOGY.....	3-1
Chapter Overview .....	3-1
System Selection .....	3-1
Performance Characteristics. ....	3-1
Proven Systems.....	3-2
System Cost Determination .....	3-2
Acquisition.....	3-2
Operation.....	3-2
System Capability Determination .....	3-3
Chapter Summary.....	3-4
IV. DATA ANALYSIS .....	4-1
Chapter Overview .....	4-1
Performance Characteristics .....	4-1
Definition of RF/ID Terms. ....	4-2
Definition of RF/ID Terms (continued).....	4-4
Conceptual Application .....	4-5
Representative System.....	4-6
Acquisition Costs .....	4-8
Transponders. ....	4-8
Reader/Interrogators. ....	4-9
System Installation. ....	4-10
Operational Costs.....	4-10
Related Studies .....	4-11
Agile Sword 1994. ....	4-11
Army TAV Study.....	4-12
Desert Storm Estimated Savings. ....	4-13
Lean Logistics.....	4-17

	Page
Chapter Summary.....	4-20
V. CONCLUSIONS.....	5-1
Chapter Overview .....	5-1
Investigative Question One.....	5-1
Investigative Question Two.....	5-2
Industry Price Ranges. ....	5-2
Representative System. ....	5-3
Acquisition.....	5-3
System Installation and Development. ....	5-3
Operation.....	5-3
Maintenance.....	5-4
Investigative Question Three .....	5-4
Investigative Question Four.....	5-5
Lost Supplies. ....	5-6
Long Requisition to Receipt Times.....	5-6
Multiple Requests for Same Part. ....	5-6
Backlogs at CONUS and Theater Distribution Nodes.....	5-7
Poor Documentation of Inventory and Receipt. ....	5-7
Investigative Question Five.....	5-8
Summary of Findings.....	5-8
Recommendations for Further Research .....	5-9
References.....	REF-1
Vita.....	V-1



## **List of Tables**

Table	Page
1. Distribution Problems Noted In Previous Conflicts .....	2-3
2. Percent of Cost Increases Between Generations of Weapon Systems .....	2-5
3. RF/ID Systems .....	4-2
4. RF/ID Systems-Continued .....	4-4
5. Candidate Systems.....	4-7
6. Benefits Summary.....	4-13

**Abstract**

The lack of asset visibility experienced at Aerial Ports of Embarkation (APOEs) during Operation Desert Storm is a phenomenon that has occurred in every major conflict for the last 40 years. The costs associated with this lack of control directly relate to the combat readiness and capability of supported units. This study examined the possibility of installing a Radio Frequency Identification (RF/ID) system to track Department of Defense 463L pallets worldwide. Performance characteristics of commercially available RF/ID systems were summarized, and a conceptual Air Mobility Command (AMC) tracking system was presented. For purposes of concept study, Amtech Corporation's Intellitag RT 2000 system was selected as the representative system. Costs to acquire, implement, and maintain the representative system approach \$77,000,000, based on AMC requirements and historical costs of similar large scale commercial systems. Projected benefits of RF/ID implementation are discussed in terms of lean logistics, estimated wartime cost-avoidance, and operational tests of similar systems.

# ***TRACKING AIR FORCE PALLETS USING RFID TECHNOLOGY:***

## ***A CONCEPT STUDY***

### **I. INTRODUCTION**

#### **Chapter Overview**

This chapter provides a background for the research topic of analyzing the advisability of installing Radio Frequency Identification (RFID) tags on Air Force 463L pallets at the present time. The general purpose of this research, the problem statement, the research objectives, and the investigative questions are presented. The scope of the research is defined within this chapter, and pertinent issues are briefly discussed.

#### **General Issue**

The task of tracking high priority cargo through the Air Mobility Command has proven to be a difficult challenge. At the peak cargo volumes experienced during Operation Desert Storm, the airlift control elements regularly "lost" important items at points between the cargo's origin and ultimate destination. This lost cargo would accumulate at aerial ports, until rediscovered days or weeks after the date the equipment was required at its final destination (Roos, 1994:30). In some cases, the location of critical items remained unknown until some time after the conclusion of the war. The costs associated with this lack of control directly relate to the combat readiness and capability of the supported units (Roos, 1994:30). Furthermore, any essential component not received by the supported unit in a timely manner frequently results in a second shipment of the required item. This redundant shipment requires additional airlift, and

decreases available item spares. As Air Mobility Command's airlift resources continue to decline, the ability to accurately track the location of in-system cargo becomes increasingly important. Timely knowledge of the status and expected movement times, modes, and priorities of proprietary cargo is essential to planning for the most efficient use of mobility airlift. For purposes of this research, the word "cargo" refers to general palletized assets, such as maintenance equipment, consumable supplies, weapon system components.

### **Problem Statement**

The cargo tracking technology employed by the Air Mobility Command is outdated and inefficient. Items shipped via Air Force 463L pallets are dependent on a paperwork intensive system to avoid being lost, delayed, or misrouted. For-profit corporations operating in a similar large scale transportation environment make maximum use of available tracking technology to remain competitive. The commercially available systems used by these specialized transportation firms may present opportunities for improvements in accuracy and efficiency within the military airlift system. For the Air Force to most efficiently utilize its future airlift resources, an effective and affordable cargo tracking system must be acquired.

### **Research Objective**

The research objective is to study the advisability of equipping Air Force 463L pallets with a Radio Frequency Identification (RF/ID) transponder system. Total acquisition and operating costs will be estimated for a representative commercially available system. The expected utility of the system will then be analyzed in relation to wartime asset visibility requirements.

## **Investigative Questions**

1. What are the performance characteristics of existing RF systems?
2. What are the costs of existing RF systems?
3. How are existing RF systems being used in comparable commercial transportation industries?
4. How can existing RF technology be applied to 463L pallets to improve the current airlift system?
5. Do the expected improvements to asset visibility indicate that an RF system should be acquired at the present time?

## **Scope**

This study concentrates on a limited aspect of the total Air Force logistics system. The 463L pallet was selected as a result of its similarities in use and purpose to commercial cargo containers, and as a result of its impact on the Air Force transportation network. To improve the efficiency of the network, this research effort attempts to apply parallel commercial transportation tracking practices to the existing Air Force cargo movement system. Although a significant percentage of assets shipped through the Air Mobility Command transportation system is not palletized, limiting initial RF/ID applications to 463L pallets will provide a base of experience from which a comprehensive system can be developed.

This concept study will follow a three part format. Initially, a market summary of competitive RF systems will be presented. Next, a conceptual model of an RF/ID enhanced 463L system will be suggested. Finally, the expected utility of such a system as a necessary component of Air Force asset visibility programs will be analyzed in relation to the calculated costs of acquisition and deployment.

## Issues

Issues which affect the return on a cargo tracking investment are briefly summarized below.

1. The cost of commercially available RF/ID systems is continuing to decrease. This steady decline in cost is attributable to two factors. First, the general market for RF applications is rapidly expanding, bringing the cost allocation benefits of large scale production and marketing. Second, the cost of the component microcircuitry is also steadily decreasing. The exception to this general decrease in cost is a category of applied RF/ID technology known as active RF transponders. Active transponders require relatively expensive batteries to provide power for their longer range transmitters, and the cost of these batteries is not projected to decline significantly in the near future. With the exception of these active transponders, the steady decrease in RF/ID cost may impact the decision to equip the Air Force 463L system with RF technology. Should currently available RF systems prove to be prohibitively expensive, future generations of systems may satisfy the same requirements at a far lower total outlay.
2. The United States' strategic airlift capacity is declining due to the age and quantity of airframes in the current fleet. As the gap between current capacity and projected wartime ton-mile requirements widens, benefits derived from improvements in utilization efficiency become proportionally more significant. In essence, the benefit derived from a cargo tracking system will vary inversely with the size and capacity of the current airlift fleet.
3. The increasing trend toward lean logistics will have the effect of reducing the quantity of materiel available for use by combat and support units. This lean logistics concept is dependent on high velocity logistics pipelines. Redundant requisitioning, a frequent occurrence during Operation Desert Storm, adds

unnecessary mass to overburdened transportation systems. Moreover, redundant requisitioning mis-allocates parts, equipment, and supplies, possibly denying these resources to units with a valid and critical need. Improved asset visibility will have the effect of reducing these redundant requisitions. Therefore, as lean logistics becomes more prevalent among existing and future Air Force systems, the benefits of improved cargo tracking techniques will also become more significant.

### **Chapter Summary**

This chapter described the overall nature of this research effort. The general issues of inadequate cargo tracking and the resultant effect on the Air Mobility Command transportation system were presented. The specific problem, the research objective, and the investigative questions for this study were defined. Finally, the scope of this research was described, and pertinent issues affecting the research were introduced. Chapter II provides a review of current literature on RF technology and the 463L pallet system.

## **II. LITERATURE REVIEW**

### **Chapter Overview**

Official Air Force Doctrine states that "Knowing with confidence where parts or supplies are located, or when and how they will arrive, is the key to the logistician's ability to support operational requirements" (AFDD-40, 1994: 11). As far back as 1974, a Department of Defense (DoD) report identified the need for improved visibility of assets. While the need was real, organizational structures required to support the improvement of In-Transit Visibility did not exist, and the necessary communications and information systems technology was not available (DoT, 1991: 1). Recognizing the growing importance of reliable and accurate cargo tracking, the Commander in Chief of Air Mobility Command in 1994 declared that year to be "The Year of In-Transit Visibility" (Fogleman, 1993). Today, ITV enjoys phenomenal interest throughout both the DoD and civilian logistics communities (Dot, 1991: 1-2).

In an effort to overcome cross-organizational barriers to ITV, the United States Transportation Command (USTRANSCOM) was tasked with wartime traffic management centralization and automated data processing integration. An important initiative in accomplishing these objectives was USTRANSCOM's development of the Global Transportation Network (GTN) (Dot, 1991: 2). The Global Transportation Network is designed to make maximum use of existing government and commercial systems to provide DoD transportation users with comprehensive deployment support (Lorraine, 1994: 34). This system, when fully developed, represents the organizational structure required to make ITV a reality. In addition to the support ITV has received from DoD organizations, technology has advanced to the point of providing DoD logisticians a wide variety of options for achieving asset visibility. Microcomputers, with large memories and



processing capabilities, permit the data capture and manipulation required for ITV.

Communications systems allow high speed data exchange with distant, isolated sites, and recent innovations permit highly accurate, nearly real time data collection. Some of these recent innovations are radio-frequency identification (RF/ID), bar coding, microcircuit smart cards, voice recognition, satellite tracking and communications, and electronic data exchange (EDI) (Dot, 1991: 2).

This chapter provides a background of recurring problems with DoD efforts to achieve the desired levels of ITV. In addition, this chapter discusses the impact of ITV on sustainment operations, and the unique asset visibility issues associated with military air transportation. Commercially available Radio Frequency Identification (RF/ID) systems will be examined in detail, as will the Air Force 463L pallet program. The characteristics of selected commercial tracking methods will be discussed, in relation to Air Mobility Command Aerial Ports. Finally, current military asset visibility programs will be addressed.

## **Recurring Problems**

An examination of historical Department of Defense information suggests most logistical asset visibility problems are far from new. A RAND study of over 40 years of documented distribution problems occurring during the Korean, Vietnam, Persian Gulf wars, and Somalia revealed obvious similarities among these conflicts. These problems have persisted in spite of numerous attempts by various organizations to improve DoD wartime distribution methods (Moore, 1993: 2). Table 1 provides a summary of the RAND findings.

TABLE 1

Distribution Problems Noted In Previous Conflicts (Moore, 1993: 2)

Problem	Conflict			
	Korea	Vietnam	Persian Gulf	Somalia
Supplies Lost	Yes	Yes	Yes	Yes
Long requisition-to-receipt times	Yes	Yes	Yes	Yes
Multiple requests for same part	Unk	Yes	Yes	Yes
Backlogs at CONUS and theater distribution nodes	Yes	Yes	Yes	No
Poor documentation of inventory and receipt	Yes	Yes	Yes	Yes

The RAND study determined that Operation Desert Storm's logistics operations experienced difficulties not unlike those in observed in earlier conflicts. Aerial ports of embarkation (APOEs) were overwhelmed with high priority assets, to an extent that logisticians lost almost complete visibility of both orders and cargo. As a result, vast quantities of these high priority assets were "arbitrarily re-packed into sea vans without documentation and shipped by surface" (Moore, 1993: 2-3). The content of these containers was therefore unknown to the receiving forces; 25,000 of the 40,000 containers arriving in Saudi Arabia had to be opened to accomplish a basic inventory and determine their destination. "Visibility of expensive, high priority materiel was lost at the APOE, and in some cases not regained until the shipment returned to the United States months later" (Moore, 1993: 2-3).

Visibility problems at ports of embarkation have been the subject of numerous studies over the years. As technologies improved long-line communications and created

faster resupply vehicles, the continuing inefficiencies at terminals within logistics chains became more painfully apparent (AFLMC, 1985: 165).

This truth has been "discovered" so often during the last twenty years that it borders on the platitudinous. The reasons for its persistence are not far to seek. It has always seemed more rewarding to work on the clean-cut problems of speeding up long-line communications and increasing the velocity of the physical movement of cargo; while it is a vexation of spirit to try to secure noticeable improvements in that messy intertwined, management information system within the confines of the base and the depot and at intransit points. (AFLMC, 1985: 165)

It appears that the same lessons are being re-learned over the course of each contingency. In 1970, the Joint Logistics Review Board (JLRB) published in its findings of the on-going Vietnam war, stating "As the buildup progressed, unprecedented volumes of traffic overwhelmed the communications systems. Despite continuing emergency programs to expand and upgrade the communications system, it was not until mid-1968 that total capacity and automated capabilities were adequate" (JLRB, 1970: 15). Perhaps even more significantly, the JLRB stated at the end of the preface to its recommendations:

The recommendations of the JLRB, when implemented, will greatly improve current logistics systems. Many of the findings and lessons learned are of permanent value and can be considered as logistics principles. Many are lessons relearned in Vietnam--lessons that were lost or obscured in the passage of time since similar Korean or World War II experiences. (JLRB, 1970: vi)

It is clear that ITV is a long overdue capability. Rising component costs, shrinking airlift fleets, and smaller inventories demand that DoD overcome the problems that have historically plagued the military logistics pipeline.

## **Materiel Costs**

The capabilities of modern weapons systems continue to increase at a formidable pace, a fact that was clearly highlighted by tremendous successes in Operation Desert Storm. However, these capabilities also have the effect of driving acquisition and support

costs to a commensurate level. Table 2 illustrates cost differences between generations of front line weapons systems.

TABLE 2

Percent of Cost Increases Between Generations of Weapon Systems

(in constant dollars) (Moore, 1993: 2-3)

Component	Model		% Increase
	From	To	
Aircraft Engine	J 79	F 100	244
Fire Control Radars	APQ 156	APG 63	1016
Helicopter Engine	T58 GE	T 700-4	353
Ammunition	8	MLRS	419
Missiles	Nike	Patriot	306

These vastly increased item costs underscore the need to move assets through the logistics pipeline efficiently. Inventory expenses are a concern in time of peace, and are significantly affected by logistics pipeline velocity. In addition, the relatively greater expenses associated with modern weapons systems have resulted in fewer copies produced, and fewer spares available. During contingency operations, the relative scarcity of these expensive assets increasingly demands a degree of pipeline visibility that has not yet been achieved (Roos, 1994: 32).

### Visibility Issues

To understand the primary factors affecting cargo tracking reliability, elements of human factors, operational considerations, and available technology will be examined.

Human Factors. With regard to human factors, the redundant entries required by current systems tend to degrade final information reliability. In effect, manual transcription and entry techniques virtually ensure a noticeable, continuing stream of data

errors. During Operation Desert Storm (ODS), a reversal of two numbers in a hand-entered DODACC code led to a massive quantity of material being shipped to the wrong location. This simple mistake resulted in enormous transportation costs; instead of a one-way shipment, the assets were returned to the origin and reshipped to the proper address. The unit that initially received the incorrect shipment was forced to commit time and manpower to correct the situation, and the original customer operated without the needed assets for an unnecessarily lengthy period of time. As a disturbing footnote to this example, over the course of ODS this exact mistake was repeated on three separate occasions by the same unit (Moore, 1993: 25). Civilian industry is not immune to similar problems. For instance, Conrail estimates that approximately 15% of its manually-entered data contain errors, which alone cost the company over \$43 million per year (Herst, 1993: 58). These human factors problems can be addressed through the removal of the human element from data entry wherever possible. Similarly, automatic data flow between system nodes offers valuable increases in data availability and reductions in errors caused by human error.

Customer behavior is affected by the unreliable performance of the current pipeline. Instances similar to the above example lead to a general distrust of the objective logistics system. Customer distrust results in rational coping behaviors, such as overstocking initial wing deployment packages or re-ordering more assets than actually required. The consequence is a sub-optimization of the performance of the overall system. A loop results: system responsiveness further degrades, customer confidence continues to decline, and the final result is less system capability (Moore, 1993:25-26).

Operational Considerations. These are primarily centered on availability of cargo tracking information at critical decision nodes within the system. These nodes include cargo onload points (airlift users), transfer, maintenance, and refueling points (primarily AMC aerial ports), and offload points (deployed locations and host bases).

Each system node makes use of the tracking data in distinct ways, and each presents a variety of independent system design considerations.

Onload points at user bases are highly dependent on accurate system information to establish complex deployment schedules of events. Base level personnel are normally well versed in operational uses of supply tracking systems; however, due to their infrequent practice with high volume airlift/cargo tracking, base level personnel are only minimally proficient in the use of these specialized systems. For this reason, the optimal system must be extremely user friendly. It must be able to interface with personnel who are highly dependent on reliable information, but who are not system experts.

For the aerial port operators and schedulers, an accurate account of all marshaled and inbound cargo permits exponential increases in efficient airlift utilization. Important information reliability considerations are derived from this necessity. First, a tremendous volume of cargo, and therefore data, flows through each aerial port throughout major contingencies. The inability of previous tracking systems to provide asset visibility has been directly attributed to this volume of data (Mueller, 1986: 1-1). Although large volumes certainly present data management challenges, Federal Express claims that the entire Operation Desert Storm sustainment was nearly identical to its annual Christmas surge (Moore, 1993: 33). Second, airlift schedule changes are extremely common. Aircraft break, or are diverted to other bases, for a variety of reasons. System flexibility is an absolute requirement due to the resultant last minute changes. These changes limit the scope and accuracy of current scheduling and tracking systems (AMC, 1994). Third, the ratio of cargo volume to available airlift reaches phenomenal proportions during contingency operations and disaster relief efforts. Many tracking sub-systems which are functionable during normal operations fail during high-volume operations, due to data overload (JLRB, 1970: 15). Again, flexibility is a key consideration.

Deployed locations present an entirely different set of system considerations. Personnel at deployed locations normally operate with limited resources. Communications, particularly with off-station locations, are at a premium (Roos, 1994: 31). Personnel at the deployed location (or host base) use the cargo tracking information for a variety of important tasks. Inbound cargo dictates available mission resources, maintenance scheduling, cannibalization requirements, fuel usage, and overall warfighting constraints (Roos, 1994: 32). Essentially, the availability of tracking data impacts the efficiency of planning "at the point of the spear." Even if the system operates 100% reliably at earlier nodes, significant value is lost if the data is not available at the deployed location. For maximum reliability and utility, great emphasis must be placed on robust communications and environmentally durable systems.

Available Technology. Capabilities offered by telecommunications and telecomputing have changed at a phenomenal rate over the last thirty years. Radio Frequency Identification tags (RF/ID) with Read Only capability are fast becoming the standard in the transportation industry (Herst, 1993: 58). These devices are integrated circuits that function as transponders, responding to electronic queries with a discreet signal when interrogated by a RF reader. The process is wireless, and line of sight is not required between reader and transponder. Also, the system is unaffected by adverse conditions such as temperature extremes, humidity, mud, and dirt (McLeod, 1993: 5).

Tracking systems based on this technology are already in use for purposes of wildlife research, cattle tracking, security, and manufacturing. More recent applications include granting access to ski lifts, tracking runners in marathons, and more equitable billing for garbage collection (McLeod, 1993: 5). Perhaps one of the most visible applications under development is a concept called Electronic Tolls and Traffic Management (ETTM). ETTM uses RF/IDs installed in participating automobiles to eliminate the need to stop at toll booths. A system currently in use on the North Dallas

Tollway enables drivers who purchase an RF/ID tag to open an account with the toll agency. When the RF/ID equipped vehicle passes the RF interrogator, the toll amount is automatically deducted from the customer's account. According to Frank Dorrance of Amtech Corporation in Dallas, the system has the capability to read a tag passing at over 180 mph, and has a probability of incorrectly reading a tag calculated at 1 in 800 million (Church, 1992: 79).

In 1992, low-end Read Only RF/ID tags cost between \$20 and \$30 (Church, 1992: 79). However, this cost has been dropping rapidly, and this trend can be expected to continue in the near future as the RF/ID market expands and production volumes increase. Representatives of Hughes Aircraft in Los Angeles estimate the worldwide RF market is worth at least \$480 million, and growing at 22% per year (McLeod, 1993a:4). An important consideration is that the International Air Transport Association (IATA) tentatively agreed that RF/IDs should replace bar code readers as the official baggage tracking technology (Fletcher, 1993:7).

Radio Frequency Identification tags with Read/Write capability offer the same advantages as the Read Only RF/ID tags, with the added enhancement information modification. Typical Read/Write chips can store up to 128 kbits of data. The technology is currently in use at Volkswagen AG's plant in Wolfsburg and BMW AG's plant in Munich, to control and track auto manufacturing processes (Gosch, 1993: 5).

When applied to AMC's cargo tracking procedures, a large memory, passive RF/ID system would provide many benefits already seen in the commercial transportation industry. Real time inventory information and lack of requirements for a large database would greatly benefit users at deployed, bare-base locations. In addition to tracking the cargo within the airlift system, the same equipment could be used to monitor critical supplies and equipment information at the point of use. Finally, when redeployment was



required, accurate and updated information could be obtained directly from the RF/ID tag on each pallet and piece of equipment (DoT, 1993:1-2).

Bar Code Readers are the current standard in a variety of commercial transportation and supply operations, including airline baggage tracking (Baggage, 1993:1). The technology is well developed, and bar code identification tags cost can cost less than a cent per unit. When applied to AMC's concept of ITV tracking requirements, bar code readers satisfy the minimum requirements. Information needed at each system checkpoint could be supplied by a bar coding. Disadvantages of the bar code laser reader include limitations of line of sight constraints, environmental visibility, and humidity (Church, 1992: 79). Also, the process of bar coding a pallet is subject to some of the same disadvantages currently made while placarding pallets for deployment. A common mistake involves the improper placement of placards, which results in partially or completely unreadable information.

### **Commercial Transportation Practices**

The operations strategies and practices of the for-profit transportation industry may hold valuable insights for military logisticians. The competitive nature of civilian industry mandates the best possible use of every available strategic advantage, meaning that those companies at the forefront of profitability have demonstrated the effectiveness of their operations. In the past, military logisticians have objected to the application of commercial practices to military transportation systems. The primary objections center on the clear differences between military and civilian logistics constraints. Among these differences are the relative predictability of surge requirements, the nature of the customer environment, funding of projects and improvements, and constraints to contracting. Each of these objections is certainly valid. Civilian industry can plan with reasonable certainty for volume spikes, while the military usually operates in a short-notice "feast or famine"

mode. Civilian transporters normally operate in known and safe environments, whereas the military is often required to move assets into unknown and dangerous locations. A particularly significant difference is the relatively stationary nature of civilian transportation terminals; the military's destinations are highly mobile. Funding for projects in civilian industry comes from investors and is flexible, whereas military funding is congressionally awarded and normally designated for specific programs. Finally, civilian contracting is relatively fast and unconstrained, as compared to the military's slow and inflexible acquisition regulations (Moore, 1993: 32-33).

Nevertheless, a number of differences between DoD and civilian industry are unjustified and inefficient. The civilian industry, for example, maintains a continuous focus on the customer at all levels of business. In contrast, the military transportation system tends to overlook the customer in peacetime in favor of localized cost reductions (Moore, 1993: 33). While this practice can optimize the operations at a given transportation unit, it sub-optimizes operations throughout the DoD.

Many civilian firms ship volumes of cargo that are equivalent to or larger than DoD activities. For example, in 1993 Caterpillar corporation shipped an average of 78,000 components per day. In 1992, Federal Express handled 1.5 million packages per day, and UPS transported a daily average of 11.5 million per day (Moore, 1993: 33-34). Emery Worldwide currently transports over 4 million pounds of freight per night (Patrick, 1995).

Although military transportation exhibits undeniable differences from civilian industry, there are clear similarities between problems facing both types of operation. The best civilian firms have already faced and overcome many of these common challenges by combining technology with organizational adjustment. The operating techniques employed by the United States transportation industry vary considerably in terms of effectiveness, applications, limitations, and cost. Despite these differences, these tracking

techniques share the common characteristic of having been proven by their success in a highly competitive market. The practices of these successful civilian firms can be used as a model for future DoD improvements (Moore, 1993: 35).

The commercial transportation industries of interest include air cargo, passenger airlines, and surface freight. Surface freight encompasses the major functions of rail, road, and ocean transportation. These large scale transportation systems can function as mesh (point-to-point) networks, as hub-and-spoke (star) networks, or as a combination of both. The following commercial transportation operations help illustrate the characteristics and requirements of these transportation networks.

Air Cargo. Commercial air cargo carriers primarily operate in hub and spoke environments (Coyle, 1994: 402). Commercial cargo items, usually in the form of individual parcels, typically originate at smaller, outlying nodes. After cargo enters the system, the carrier transports the parcels directly to a central facility, or hub, where all arriving cargo is sorted and forwarded according to its final destination. In the most basic hub network scenario, cargo moves through two transportation phases and one sorting, or classification phase. Tracking cargo in a transportation, or en-route phase, requires two pieces of information. First, the tracker needs to know on which aircraft the cargo is being transported. Second, the tracker needs to know where that aircraft is within the system. Tracking cargo at the hub, or in the classification phase, is a more challenging exercise. Cargo in the classification phase can be physically located anywhere within the geographical confines of the hub facility (Patrick, 1995). As a result, tracking is normally accomplished using one of two techniques.

First, cargo can be tracked as a function of its progress through specific stations within the facility. As an example, if a classification facility operates with five stations, A through E, and a particular parcel is known to have passed stations A, B, and C, the company can reasonably expect the parcel to be currently located between stations C and

D. For this system to function effectively, each parcel must move through a specific preplanned sequence of stations. In the above example, if the parcel had simply skipped station D without record, the company's previously reasonable assumption about the parcel's current location would then be incorrect (Patrick, 1995).

A second tracking technique requires continuous, real-time updates of a parcel's location. With this tracking technique, the exact location of a parcel is known from the moment parcel enters the classification center (Gosch, 1993: 5). This technique presents information in many ways similar to the information displayed on an Air Traffic Controller's radar scope, where the controller sees the exact locations of all aircraft currently located in their sector of responsibility.

Scheduled Airlines. Commercial air passenger carriers operate in combination environments, displaying aspects of both mesh and hub networks. A commercial airline functions as a mesh network when a direct flight transports passengers from their origin, non-stop to their final destination. In a pure mesh network scenario, only one phase of transportation is required, and in-transit tracking requires only the knowledge of aircraft location. Commercial airlines also route passengers through central hub facilities, similar to commercial cargo carriers. The nature of information requirements in the scheduled passenger carrier scenario is similar to commercial cargo carriers at hub operations, due to the transportation requirements of passengers' baggage. Tracking at these airline hubs is normally accomplished by recording progress through specific stations at each location via bar code readers (Baggage, 1993:1).

Surface Freight. Surface freight also displays characteristics of both networks. The rail industry employs microwave technology in controlling its operations (Coyle, 1994: 401). Rail cargo is sometimes tracked in both the hub and en-route phases of transportation using bar-code "license plates" attached to each rail car. More recently, the rail industry began making heavy investments in RF readers. Conrail, for instance,

recently spent close to \$20 million to install 200 RF readers along its track network. The investment also included another 2000 RF readers that will be required to link Conrail to its trading partners, such as Union Pacific. A similar recent investment by Norfolk Southern was estimated to have saved the company over \$2 million dollars in the first year due to more efficient operations and locomotive management. In addition to bettering operations efficiencies, Conrail's decision to invest in this RF system was driven by expected improvements to customer service. These improvements included "100 percent accurate reporting of shipment location, scheduling and tracing; reduced facility requirements for storage, tracks, warehouses and tanks; support for just-in-time production scheduling; and improved inventory control and reduced carrying costs" (Herst, 1993: 61).

The increasing containerization of intermodal cargo is driving a trend toward use of RF/ID throughout the surface transportation industry. The ocean transportation firm Matson Navigation installed RF tags on over 22,000 of its containers, and American President Lines accomplished the same with approximately 100,000 of its containers. The trucking firms J.B. Hunt and Schneider are currently studying the possibility of installing RF tags on their truck and trailer fleets, largely due to their interoperability with railroads (Herst, 1993: 61).

### **Air Mobility Command Aerial Ports**

The United States Air Force Air Mobility Command (AMC) functions both as a cargo carrier and as a passenger carrier. For initial wartime deployment, point-to-point networking is normally used in AMC's cargo operations. Deploying personnel and cargo are transported directly from the military base of origin to the airfield closest to its final destination. For peacetime operations and wartime sustainment efforts, assets are primarily transported using a hub-and-spoke system with aircraft scheduled on an as-

needed basis. Groups of passengers and cargo not large enough to justify a dedicated airlifter are transported via channel air, which consists of scheduled military flights between airlift hubs and other designated bases. Personnel and cargo are transported in channel air on the basis of pre-assigned priority and chronological entrance into the airlift system (Larberg, 1992: 25). Cargo with a high pre-assigned priority can bump cargo already on board an aircraft transiting a hub. These hubs, also called AMC aerial ports, can therefore accumulate large quantities of cargo during periods of unusually high volume. During Operation Desert Shield/Desert Storm, AMC aerial ports such as Dover AFB, McGuire AFB, and Charleston AFB accumulated cargo faster than it could be forwarded (Moore, 1993: 17). In many cases, shipping documentation was lost in the interim, resulting in delayed support for the deployed units and additional cargo accumulation at the aerial port (Roos, 1994:31).

### **Systemic Visibility Initiatives**

Recognizing the critical nature of resupply in a wartime environment, AMC is in the process of developing a comprehensive tracking system centered on improving Intransit Visibility. According to the Headquarters Air Mobility Command ITV cell, this system will provide the capability to track cargo and passengers in the air transportation system. For instance, the projected ITV system will be able to tell when the "next shipment of fuel or ammo is due in or, perhaps more importantly, when the freedom bird will touch down so your family and friends can meet you" (Department of the Air Force, 1994:1-2). This tracking system will rely heavily on a comprehensive database of all cargo currently in the air transportation system, in conjunction with progress updates provided as each piece of cargo transits tracking stations within the system (Gregorcyk, 1994). The system, as it is currently proposed, will dramatically improve information available about the general location of cargo within the airlift system. However, during periods of

extremely high volume, such as another regional crisis, cargo may again accumulate at various aerial ports. Integrated databases of current systems, such as the Cargo Movement Operations System (CMOS), will mitigate some of the problems contributing to lost cargo experienced during Desert Shield/Desert Storm, but will not ensure complete accountability (DoT, 1991: 20-21). To improve cargo accountability in such a scenario, currently available commercial tracking systems could be employed at each of the aerial ports, and integrated into the planned ITV systems.

## **Chapter Summary**

The importance of ITV has been clearly recognized by the military logistics community. The problems which stand in the way of achieving ITV are the same problems that have plagued military logisticians for hundreds of years. However, recent DoD organizational changes and rapidly advancing technology have opened the door for phenomenal improvements in asset visibility. Increasing cost of components, declining airlift capacity, and shrinking support inventories mandate the exploitation of this possibility. Civilian industry is far ahead of DoD in the strategic use of new cargo tracking technologies. Although there are undeniable differences between military and civilian transportation requirements, there are also many similar constraints which commercial firms have already overcome. The highly competitive commercial industry has ensured that only the most effective systems have prospered. As a result, military logisticians can learn valuable lessons from private industry. One of the fastest growing commercial innovations is Radio Frequency Identification, or RF/ID. This system holds great potential for dramatic improvements in Air Force ITV.

The following chapter describes the specific methodology for this research effort.

### **III. RESEARCH METHODOLOGY**

#### **Chapter Overview**

The objective of this research is to study the advisability of integrating RF/ID technology into the Air Force 463L pallet system. To accomplish this objective, a series of determinations and analyses are accomplished. First, a commercially available, representative RF/ID system is selected. Second, the cost of acquiring and integrating this system into the current transportation network is determined. Third, the manpower and monetary advantages of similar systems as acquired or proposed by sister services are discussed. Fourth, the relationship between lean logistics and wartime asset visibility is explained, in relation to RF/ID capabilities.

#### **System Selection**

A commercially available RF/ID system must be selected for purposes of concept evaluation. This system must possess performance characteristics and support requirements compatible with the current AMC operating environment. Proven RF/ID systems that are currently used in comparable transportation environments are given priority consideration. Although optimizing the selection of a RF/ID system is not the goal of this research effort, a representative system is selected that demonstrates the costs and capabilities associated with RF/ID acquisition, deployment, and operation.

Performance Characteristics. The performance characteristics of commercially available systems are identified by manufacturer and system. These performance characteristics include the following items: line-of-sight requirements, read/write capability, memory size, range, multiple tag read capability, frequency, requirement for FCC site license, time to download, and handheld interrogator availability. Any RF systems whose performance characteristics are clearly unsuitable for use in the AMC



transportation environment, such as those with ranges less than two meters, are eliminated from consideration for the representative evaluation system.

Proven Systems. Various RF/ID systems have seen extensive use in a number of commercial operations, such as container shipping, toll collection, and materials tracking. These industrial applications are examined for evidence of clearly demonstrated successes, especially in operations that parallel the AMC 463L environment. A proven, successful RF system capable of operating in conjunction with the 463L system offers a realistic basis for a concept investment evaluation.

### **System Cost Determination**

Total outlays required to deploy the selected system are determined from available information. These costs are be segregated into components of initial acquisition and continuing operation.

Acquisition. Initial system acquisition requirements are divided into components of hardware and system development costs. System hardware, such as the pallet-mounted RF transponders, are costed on a per unit basis, and then multiplied by the total number required to achieve the planned coverage. To accomplish this calculation, the number of Air Force 463L pallets currently in service is determined, as is the number of interrogator stations and data terminals needed for worldwide coverage. Cost data is extrapolated from similar systems already in use in related sectors of the transportation industry. System development costs, such as programs required to initially configure and install the system, are costed separately.

Operation. The predicted annual costs associated with operating and supporting the RF system throughout its life-cycle are determined. Items of interest include scheduled maintenance, corrective maintenance, and allowance for failures (Blanchard,

1992: 424). These costs are extrapolated from historical data on currently operating systems, and from data provided by industry sources.

### **System Capability Determination**

Unique challenges are presented when attempting to recognize the full set of advantages that result from large scale implementation of new technologies (Horngren, 1994: 704). From a military perspective, traditional methods of payback analysis are not fully applicable. Due to the lack of profit orientation, revenue benefits are non-existent. Direct cost savings might result from increased efficiencies derived from this system, although these savings would be difficult to isolate among the multitude of other factors affecting AMC operations expenditures. Examples of some of these direct cost-avoidance advantages are apparent in sister services' evaluations of similar systems. While these direct cost avoidance advantages are attractive, far more significant and noticeable benefits will take the form of more effective control mechanisms, such as improved asset visibility and increased responsiveness in the movement of prioritized assets. The resultant system control capabilities permit implementation of the advanced, high velocity, cost saving movement protocols on which current inventory reduction initiatives depend.

As lean logistics procedures become the standard in Air Force operations, asset visibility will rapidly transition from its current status as a convenience or luxury to the AMC customer, and become an absolute necessity for continued combat capability. Reduced inventory levels and a steadily decreasing strategic airlift capacity necessitate a tighter control over prioritization within the logistics pipeline. Benefits which answer needs of this nature are difficult to independently quantify in financial terms, but are perhaps even more important than direct cost savings in terms of overall mission impact (Horngren, 1994: 704-705). To illustrate the far-reaching control advantages of RF/ID,

the projected capabilities of this system are related to the published wartime requirements of lean logistics.

### **Chapter Summary**

This chapter provided the research methodology that is used to answer the investigative questions found in Chapter I. The development of the research plan is presented, and the data required to accomplish this research is discussed. The next chapter describes the analysis of the representative RF system.

## **IV. DATA ANALYSIS**

### **Chapter Overview**

This chapter presents the information obtained while researching the issues proposed in Chapter III. Performance characteristics of commercially available RF/ID systems are summarized, and a conceptual AMC tracking system is discussed. A representative system is selected, and system cost estimates are provided for transponders, readers, and maintenance. Total system implementation requirements are estimated. Operational tests and proposals of similar military systems are discussed. Related wartime cost avoidance data is presented, and relationships between wartime asset visibility, lean logistics, and RF/ID are discussed.

### **Performance Characteristics**

Numerous companies have developed RF/ID products with potential applications in the military airlift environment. The characteristics of these systems vary in a number of respects. The tables 3 and 4 summarize the characteristics of interest associated with each system.

TABLE 3

RF/ID Systems (AFMC, 1995)

Company	Active/ Passive	Line of Sight Required?	Read/Write	Memory Size	Range
ASGI	Passive	Yes	Yes	115 bytes	<2.5 meters
AT/Comm	Active	No	Yes	10 Kbytes	>2000 feet
ID Systems	Active	No	Yes	64 Kbytes	50 meters
Intellitag	Passive	No	Yes	2 Mbytes	>10 meters
Rand Technologies	Active	No	Yes	128 Kbytes	150 meters
Saab Scania Combitech	Passive	No	Yes	8 Kbytes	>10 meters
Savi Technology	Active	No	Yes	128 Kbytes	150 meters
Single Chip Solutions	Passive	Yes	Yes	1 Kbyte	<2 meters
Texas Instruments	Passive	No	Yes	512 bits	<2 meters
XCI	Passive	Yes	No	26 bits	10 meters

Definition of RF/ID Terms.Passive and Active.

Radio Frequency tags and interrogator/readers communicate through radio frequency radiation. Active tags respond to a broadcast query using electrical power supplied by a dedicated source, such as a large battery located on the tag. Passive tags respond to queries using energy reflected from the interrogation signal itself. These tags derive their energy from either the interrogation signal's magnetic field or its electrical field. If the passive tag utilizes the magnetic field, it is known as an inductive tag and will normally operate only over very short communication distances. If it utilizes the electrical field, it is called a backscatter or reflective system and is usually effective over much longer communication distances. The longest communication distances are typically achieved by

active tags, as a result of the relatively stronger power supplied by their internal batteries (AFMC, 1995).

Current industry prices ranges for RF tags are significantly different between active and passive systems. The price range of passive tags runs between less than \$1 to approximately \$75. Active tags start at \$55, and can cost as much as \$200 depending on memory and features. As a rule, costs are moving down due to increasing industry volumes and competition. The exceptions to this cost reduction are the active tags, which are dependent on large, relatively expensive batteries (AFMC, 1995).

Useful battery life is also dependent on the choice between active and passive tags. Passive read-only tags usually have no battery, and consequently have an almost unlimited useful lifetime. Passive read/write tags normally have a battery used only for memory maintenance, which provides highly predictable tag lifetimes of up to 10 years (Landt, 1995). The battery lifetimes of active tags is highly variable, depending on the number and frequency of interrogations. The batteries in these tags can last anywhere from a few months to 5 years, based on use and system (AFMC, 1995).

Range. The effective communication distance between the tag and the interrogator (AFMC, 1995).

Line-of-Sight. Communication signals used in RF communication systems can travel from the transmitter to the receiver on a straight line, or via scattered reflections from man-made or natural obstructions. For a passive system to operate properly, sufficient radiation must arrive at the receiver to 1) convey the transmitted data, and 2) power the response transmission. As a result, passive systems experience a more noticeable degradation of performance when communication is not line-of-sight. Active systems' communications are less affected by line-of-sight requirements, due to the on-board power supply available for transmission response (AFMC, 1995).

Read/Write Capability. Read-only tags can be encoded with data only once, which is typically accomplished during production. Read/Write tags have memories which may be altered repeatedly by the user (AFMC, 1995).

TABLE 4

RF/ID Systems-Continued (AFMC, 1995)

Company	Multiple Tag Read Capability?	Frequency	FCC Site License Required?	Time to Download 128 Kbytes	Handheld Interrogator Available?
ASGI	Yes	66/132 KHz	No	Not applicable	No
AT/Comm	Yes	2.45 and 5.8 GHz	Yes	<30 minutes	Yes
ID Systems	Yes	UHF, 915 MHz and 2.54 GHz	No	2 minutes	Yes
Intellitag	Yes	915 Mhz and 2.54 GHz	Yes	<4 seconds	In development for active tag
Rand Technologies	Yes	903-928 MHz	No	<2 minutes	In development
Saab Scania Combitech	Yes	2.45 and 5.8 GHz	No	<5 seconds	Yes
Savi Technology	Yes	433 MHz	No	<28 minutes	Yes
Single Chip Solutions	Yes	125 KHz	No	Not applicable	Yes
Texas Instruments	No	120 KHz	No	Not applicable	Made by other companies
XCI	Not in current products	915 MHz	No	Not applicable	In development

Definition of RF/ID Terms (continued).

Multiple Tag Read Capability. Occasionally all tags in a given location must be identified. Without multiple tag read capability, a simultaneous response from all

tags with the interrogation range would be received as "noise" by the RF interrogator. A variety of systems has been developed to permit mass tag interrogation, including randomizing the response of each tag into discrete time slots, or having each tag communicate on slightly different frequencies (AFMC, 1995).

Data Rate. This performance criterion denotes rate at which information can be written to or read from a tag. Due to error checking and tag memory management, the full rate is not actually achieved in normal operations (AFMC, 1995).

### **Conceptual Application**

Within the constraints of currently available technology, an Air Mobility Command RF/ID system should provide near-instantaneous information on the status and location of all palletized assets moving anywhere within the airlift system. To achieve this requirement, a permanent worldwide network of RF/ID interrogator/readers would be linked to a central database or databases. This reader/database information linkage could be constructed in a fashion similar to that currently employed by the major United States railroads. In the rail industry, high volume nodes are linked to databases via dedicated data lines, while lower volume and alternate nodes periodically batch flow data via modem transfer or satellite link to the central database (Klapperich, 1995).

The need for real time cargo information at deployed locations necessitates a read/write tag with memory adequate to retain inventory and transportation information. Interrogation range should be as long as possible, with line of sight not a requirement for a successful interrogation. Multiple tag read capability is essential, and information downloading time should be as rapid as possible. Finally, handheld interrogation ability should be available.

The choice between an active or passive system involves tradeoffs of range, cost, size, durability, and effective transponder life. Interrogation ranges available with most



active systems are typically effective to at least 150 meters, while passive “backscatter” transportation tags can be read only up to approximately 200 feet under the best of conditions (Landt, 1995). Active tags typically sell for many times what a passive tag costs, and are generally bulkier due to the requirement for the larger battery required to power the active transmissions (AFMC, 1995). The small design of the passive tags makes them generally more durable than their larger active counterparts, a feature that is assisted by the seamless housing characteristic of passive RF transponders (Landt, 1995). As previously stated, battery life for active transponders is highly variable, ranging from a few months to nearly five years. This variable operational life is dependent on the number of interrogations directed at a given transponder. Battery life for the passive tags used in the transportation industry can normally be expected to exceed ten years. This longevity is achieved regardless of frequency of interrogation, because reflected interrogation energy powers the passive tags’ response transmissions. The sole function of the battery in the passive RF/ID transponder is memory maintenance (Landt, 1995).

Due to the volume of 463L pallets in the DoD inventory, the random movement of each pallet throughout the system, and the probable differences in use rates, active tags would appear impractical to maintain at the present time. This consideration, in conjunction with the lower cost and greater durability of passive tags, outweighs the longer range of the active system as the primary selection factor. For these reasons, the projected 463L RF/ID system would utilize passive transponders.

### **Representative System**

Each of the characteristics identified above was considered when selecting the representative system from a market study of commercial RFID manufacturers. Due to requirement that the system be able to operate in both austere, isolated locations and large cargo yards, a minimum range of 10 meters was identified as the first criterion for the

process of candidate elimination. Next, due to inventory and transportation data requirements, systems with conspicuously slow data transfer rates or without read/write capability were eliminated. The three systems that remained were compared on the basis of price, memory size, active/passive transmission architecture, data transfer rate, and range.

TABLE 5

Candidate Systems

Company	Price	Memory Size	Architecture	Data Rate	Range
Rand Technologies	\$100-\$300	128 kbytes	Active	<2 minutes	150 meters
Intellitag	\$35-\$75	2 mbytes	Passive	<4 seconds	>10 meters
Saab Scania Combitech	\$32-\$40	8 kbytes	Passive	<5 seconds	>10 meters

Although Rand Technologies' system provided a much greater range than either of the other two systems, it did so at many times the cost and with a much slower data transfer rate. In addition, this system operates using the active architecture, which could result in battery management difficulties due to relatively short and variable battery life-spans.

The remaining two systems, Saab Scania Combitech and Intellitag, were similarly matched in range, data flow rate, and transmission architecture. The Saab Scania Combitech system was moderately less expensive, but provided a tiny fraction of the memory available with the Intellitag system. Saab Scania Combitech is a corporation headquartered in Sweden, while Intellitag is produced by Amtech, which is headquartered in the United States.

Amtech's Intellitag was chosen over Saab Scania Combitech as the representative system for this study, due to the far more powerful memory available at a slight increase in

cost. Nationality of the supplier was also a consideration in choosing the representative military system.

It is important to realize that this selection does not imply that Amtech offers the optimal system for DoD use, but merely that Amtech offers a proven system that meets the stated requirements at a moderate price relative to the industry average. Amtech RF/ID systems are currently in use on all major rail lines and a number of intermodal container carriers within the continental United States. Within the rail, intermodal, and trucking industries, "Read-only" tags are the current industry standard (Amtech, 1995). Amtech corporation is also the provider of RF/ID systems for deep-water shipping firms, such as Matson Shipping and American President Lines, and for at least one airline, JAL. The demonstrated successes and availability of historical costs of these commercially available RF/ID systems offer an excellent basis for a concept investment evaluation.

The specific RF/ID system chosen for concept evaluation was the Intellitag IT 2000, created by a consortium between Amtech and Motorola. This system offers a realistic combination of the characteristics most desirable for AMC applications that are currently available and proven in the commercial industry. Due to Intellitag's median price range, proven success, and desirable characteristics, this system provides reasonable approximation of what the Department of Defense could expect to spend if a RF/ID system were acquired at the present time.

### **Acquisition Costs**

The major hardware investments required to implement and install the representative system include transponder "tags" for each 463L pallet and sufficient reader/interrogators to provide complete coverage of the AMC air transportation system.

Transponders. Base price for an Intellitag RT 2000 passive transponder is \$32 per tag, including expected volume discounts. An optional RS 232 interface would cost

an additional \$15 per tag, which would permit standard retail RS 232 equipped handheld readers to access, read, and program the memory of each transponder. This feature would allow personal/laptop computers equipped with the same interface to accomplish the same tasks, permitting greater flexibility for deployed or isolated units. These tags are available in a ruggedized version, costing approximately \$2 more per unit. In total, the representative system transponders configured in this manner would cost approximately \$49 per unit (Brown, 1995).

At present, exactly 161,919 pallets are on record in the Department of Defense inventory (Humphries, 1995). Although only 117,361 of these 463L pallets are assigned to the United States Air Force, individual pallets are in practice freely exchanged during normal support operations with sister services (Humphries, 1995). As a result, this tracking system affords the same asset visibility potentials to all users of the AMC airlift system. At \$49 per unit, the total cost to equip each of these pallets with an Intellitag RT 2000 amounts to \$7,934,031.

Reader/Interrogators. At the expected volumes, the standard fixed-base Intellitag RT 2000 reader/interrogators would conservatively cost the Air Force approximately \$4000 per copy (Brown, 1995). According to historical data, the largest commercial transportation yards achieve complete coverage with no more than 30 readers. Smaller yards typically employ five readers, with isolated and standby sites using two readers to scan their more infrequent traffic (Brown, 1995).

Air Mobility Command operates 21 primary hubs worldwide, as identified by extremely high concentrations of dedicated material handling equipment (MHE). Approximately 154 additional locations receive regular shipments of airlifted cargo, with 136 sites serving as detachments or low-activity locations (Gibson, 1995). Applying the recommended reader/interrogator coverage to each location yields a requirement for 1672 units worldwide. With the inclusion of deployable packages suitable to equip 4 major

hubs, 10 high volume locations, and 15 detachments, the total Air Force requirement comes to 1872 reader/interrogator units. At a cost of \$4000 per unit, the total projected cost for interrogator/readers is \$7,488,000.

Combined, the required hardware package of transponders and readers would cost the Department of Defense \$15,422,031. Volume discounts are factored into the unit price of each item.

System Installation. Total hardware expenditures of similar large RF/ID systems typically account for only a fraction of the total installation and development costs. Industry experience indicates that initial expenditures for tags and readers have consistently run between 20% and 25% of the final acquisition, installation, software development, and integration costs (Brown, 1995). Using this as a guide, the more conservative figure of 20% yields a total required initial investment of \$77,110,155. This figure includes all costs associated with system acquisition and deployment.

Operational Costs. Maintenance expenses associated with the passive RF/ID transponder (tags) are essentially zero. Mean Time Between Failures (MTBF) is astronomically high, and battery replacement at the end of the tag's ten year life-cycle is currently viewed as prohibitively expensive. The reader/interrogator units have a demonstrated MTBF of 20,000 hours. When failures occur, the industry standard is a repair charge of 10% of the unit's purchase cost, or \$400 (Landt, 1995). Assuming the worst case scenario of all readers operating continuously, the annual expected repair cost becomes \$328,150. Despite the almost non-existent hardware maintenance expenses, system software maintenance and upgrades normally approach 5% to 10% of the initial system acquisition cost per year. Taking a conservative position, approximately \$8 million per year would be required to operate and maintain this system.

## Related Studies

Operational tests and concept evaluations performed by other services revealed significant monetary and manpower savings attributable to similar RF/ID systems. In addition, an analysis of transportation data from Operation Desert Storm highlighted a wide array of areas in which lack of cargo visibility resulted in dramatically increased operational, supply, and transportation costs. These studies provide insight into the opportunities available through technologically enhanced cargo tracking methods.

Agile Sword 1994. Agile Sword 1994, a Maritime Prepositioning Force (MPT) offload exercise, was the first operational evaluation of the Marine Corps' test Microcircuit Technology in Logistics Applications (MITLA) RF/ID system. This exercise took place at Camp Lejeune, NC, from 6 August 1994 through 23 August 1994. Three primary tasks were accomplished during the exercise.

1. Document the flow of equipment and provide a reconstruction of the offload.
2. Analyze the accountability and tracking performance of MITLA.
3. Determine any efficiencies provided by an automated system such as MITLA (Taylor, 1995).

The exercise plan called for 80 containers and 447 principal end items to be offloaded and throughput to unit level over a 6 day period. The movement of these assets was to be tracked both manually and via an RF system. According to the final report, the Marines found that their RF system provided tracking accuracies greater than 93% for Principal End Items (PEIs), including vehicles and other rolling stock. For containers, the RF tracking accuracy was better than 97%. Although the overall level of cargo visibility observed in this exercise lags somewhat behind tracking accuracies in commercial transportation systems, the figure was achieved by personnel relatively inexperienced in the use of the MITLA RF equipment. The chief hindrances to 100% tracking accuracy stemmed from reader/interrogator placement and from exercise preparation mistakes that

caused less than 100% of the exercise assets to be tagged with RF transponders. Other efficiencies observed during this exercise included significantly fewer Marines required to track inbound assets; whereas the current bar-code driven system, LOGMARS, required 30 marines, the MITLA RF required only 9 to achieve complete coverage. Furthermore, the speed of data collection using the MITLA RF system was far superior to that of LOGMARS. Although scanning a piece of equipment using a LOGMARS bar code reader requires only a few seconds, the action must be repeated for each asset delivered. In a large cargo yard, this process can consume hours to accomplish, versus minutes for the MITLA RF system. During a high intensity offload operation being tracked by the current system, the pace can be hindered by the data collection speed limitations. In contrast, the MITLA RF system can instantly collect data as frequently as required (Taylor, 1995).

Other advantages of the MITLA RF system included offload preparation, connectivity, and information availability. Although offload preparation was not a rated portion of the exercise, observers and participants agreed that preparing MITLA tags for deploying assets is a far quicker process than preparing LOGMARS labels. The software architecture used to connect MITLA reader/interrogators with the central data computer operated perfectly throughout the exercise. Wireless modems linked the readers with the computer, and provided exercise personnel with a real-time picture of asset location. Remote sites not equipped to flow data through the wireless modems sent a courier disk with updates at regular intervals (Taylor, 1995).

Army TAV Study. According to an economic analysis performed by the United States Army for its Total Asset Visibility (TAV) initiative, significant peacetime monetary benefits can be expected from implementation of the proposed TAV system. The economic analysis states that TAV will require “technological enhancements to existing systems” (TRESP, 1993). A key component in the proposed TAV system is the staged

deployment of RF hardware to selected Army units worldwide. The study identified peacetime asset redistribution as resulting in the largest monetary cost-avoidance benefit, due to reduced inventory carrying costs. This proposed asset redistribution would be possible due to increased visibility and control over individual equipment items (TRESP, 1993). The investment/benefit ratio for the system was identified as 14.5, with a payback period of 15 months (TRESP, 1993).

Desert Storm Estimated Savings. The Volpe National Transportation System Center conducted preliminary estimates of some costs that might have been avoided during Operation Desert Storm had real-time transportation information and automated data collection systems been available. A summary of the findings appears in the table below.

TABLE 6

Benefits Summary (Estey, 1993)

ACTIVITY	ESTIMATED SAVINGS
1. Opening Container to Resolve Discrepancy	\$1,500,000
2. Shipping Unnecessarily Reordered Items	\$15,625,000
3. Returning Excess Items	\$3,906,000
4. Frustrated Containers	\$6,250,000
5. Manual Reconciliation	\$40,000
6. Container Handling	\$6,000,000
7. Non-categorized Cargo	\$61,000,000
8. Key punch Data Entry	\$322,560
9. Storage Costs	Unknown
10. Costs Due to Units Retaining Containers	Unknown
11. Ability to Divert an Item	Unknown
12. NMCS (Class IX) Lost Mission Capable Days	\$75,000,000
13. Delays in the Receipt of Munitions Items (Class V)	Unknown
14. Delays in the Receipt of End Items (Class VII)	Unknown



Opening Container to Resolve Discrepancy. Approximately 62.5% of the containers shipped to Operation Desert Storm arrived without documentation, which required a variety of manpower intensive actions to determine contents and destination. The average time to open a container was estimated at two hours by the CASCOM. This figure included the physical opening process, looking for paperwork, handling material, and recreating paperwork. An average labor cost per hour assumes personnel costs at two E-2s at 5.20 per hour per individual, one E-4 supervisor at 7.00 per hour, and one E-7 at 10.50 per hour. Communications and materials costs are estimated at \$2.10 per container (Estey, 1993).

The estimate of \$1,500,000 accounts only for the base pay labor costs directly associated with the physical process of opening and gathering information on each container. Actual labor costs would be much higher. Furthermore, the net impact of the lost man-hours results in further backlogging of arriving cargo, multi-handling of containers to make room for new arrivals, and cargo lost due to lack of control at the sorting location (Estey, 1993).

Shipping Unnecessarily Reordered Items. Customers often reorder items when requisitions are not received within a reasonable time. When computing this transportation cost, the formula used was the number of containers in the pipeline, multiplied by the number of frustrated containers, multiplied by the percent of cargo reordered, multiplied by shipping cost of a typical container load. In this computation, an assumption was made that half, or 12,500, of the opened containers were at least temporarily frustrated. A container shipping rate of \$5,000 per container was used (Estey, 1993).

The total figure of \$15,625,000 accounts only for estimated shipping costs of reordered assets. It does not account for the additional burden on the in-theater

transportation system, nor does it account for the potentially disastrous effects of mis-allocation of critical parts and supplies (Estey, 1993).

Returning Excess Items. When containers arrived in Operation Desert Storm with duplicate order and shipping information, it was normally returned to the originating agency. The transportation costs for this redundancy were computed by multiplying the number of containers with duplicate cargo by the percentage of the same returned as excess, with the total multiplied by average container shipping costs.

The unnecessary transportation cost increase of \$3,906,000 does not account for the percentage of items that were burned, buried, or disposed of by other means (Estey, 1993).

Frustrated Containers. Cargo that could not be advanced to deployed locations due to lack of documentation was categorized as "frustrated cargo." When cargo frustration occurred, additional costs would be incurred due to the associated storage, handling, and container demurrage. Total demurrage was computed by multiplying the number of frustrated containers by an average commercial demurrage rate, by the average number of days each frustrated container was delayed (Estey, 1993).

Manual Reconciliation. Arriving containers must be reconciled with available information about inbound assets, or added to arrival documentation. The cost to reconcile each container was conservatively estimated at \$1.00 per container (Estey, 1993).

Container Handling. When cargo arrived without adequate notification to permit reception planning, containers already at processing centers were needlessly handled multiple times. The total container handling cost was computed to be \$6,000,000, which was computed by multiplying the total number of containers shipped by the estimated cost to handle one container, multiplied by the average number of times each container was unnecessarily handled at a single location (Estey, 1993).

Non-Categorized Cargo. All cargo shipped without proper documentation was categorized as "Not Otherwise Specified" (NOS) freight, and shipped at a substantially higher rate than similar, properly categorized cargo. Estimates indicate that approximately 10,000 containers were needlessly categorized as NOS, and shipped at a rate that was \$6,100 per container more expensive than cargo with full documentation, yielding a total unnecessary expenditure of \$61,000,000 (Estey, 1993).

Keypunch Data Entry. As cargo arrived at ports and final destinations, distribution information was entered via keyboard into DoD movement databases. The total time required to input the movement data for containers arriving in SWA was 46,080 hours, at a cost of \$322,560 (Estey, 1993).

Not Mission Capable Supply Costs (Class IX). This figure reflects the cost of an inoperative, representative weapons system. The cost is computed only for the percentage of tanks inoperative in the SWA theater, and is based on financial estimates of the costs of needlessly inoperable assets. The formula multiplied the 1,000 tanks in theater by the \$25,000,000 cost of each tank. The result multiplied by the 10% rate that was considered Not Mission Capable due to Supply (NMCS), and by an assumption that 10% of those inoperative assets could have been repaired if an item already in theater could have been located. This number was multiplied by a three day order and ship time (O&ST) assumed for high priority shipments. It is readily apparent that the resulting cost of \$75,000,000 is extremely dependent on the given performance assumptions (Estey, 1993). However, this figure illustrates the phenomenal potential benefits of improved asset visibility on only one major weapons system. Similar computations performed on other high cost weapons systems, such as fighters, transport airlifters, or command, control and communications aircraft, would undoubtedly reveal a pattern of tremendous potential benefits. This figure is a financial representation only; it is probably impossible to accurately represent the cost of a Not Mission Capable tank to a battlefield commander.

## Lean Logistics

The overarching benefit of an effective RF/ID cargo tracking system is that it can provide “near real-time transportation and supply information to commanders, managers, logisticians, and customers” (Estey, 1993). This capability results in more effective logistical management decision making, creates trust in the system, and supports asset accountability (Estey, 1993).

The goal of lean logistics is to increase responsiveness while reducing costs. While estimates of cost savings vary among studies, one Dyna-METRIC analysis estimated that nearly \$960 million worth of stock is required to support the current F-16C force. Using the conceptualized lean system, the stockage requirements drop to only \$320 million, with a savings of \$640 million. The same study estimates lean logistics procedures could reduce the total \$30 billion Air Force reparable spares inventory by between 60%-65% (Cohen, 1994).

A frequently stated requirement for an effective wartime lean logistics system is the need for greater control over supply assets within the transportation system. For this highly touted initiative to succeed, “unprecedented responsiveness, flexibility, and economy of effort” must be attained by all participating organizations (Cohen, 1994). In an effort to overcome many of the delays and losses of visibility that occur within the military airlift system, a Rand Corporation study recommends maximum possible use of civilian overnight carriers. However, the same study recognizes that civilian transportation will not be a viable option in many foreseeable contingencies, forcing lean logistics depot shipments to deployed locations to move via military airlift (Cohen, 1994). Although not specifically stated in the study, the same requirement to move via military airlift would logically be imposed on retrograde movement of components from the theater of operations. A General Accounting Office report to Congress found that most

retrograde movement of assets during Operation Desert Storm was “highly vulnerable to loss or theft” due to a lack of both visibility and accountability (GAO, 1992).

Although the representative RF/ID system would not directly eliminate problems related to asset accountability, USTRANSCOM has identified the requirement for some form of automated information technology as being “absolutely essential at every significant node in the logistics pipeline” to achieve in-transit visibility within the Global Transportation Network (USTRANSCOM, 1994). The “USAF Baseline Lean Logistics: Master Plan and Road Map” itself identified “Manual Tracking of Data” as the number one workaround required for successful implementation of lean logistics procedures.

Current systems are too cumbersome to effectively manage, track and score (flow days) items one at a time. Systems must support business activity, i.e. actual cost accounting and tracking through a system, not pencil and eraser. Currently, manual inputs contribute to errors. (USAF, 1995)

Based on the above information, it is apparent that implementation of lean logistics is proceeding on the basis of presently incorrect assumptions about transportation system performance. One of the five tenets of lean logistics is to “Develop just-in-time logistics to make materiel and distribution processes more responsive and reduce inventories and management intervention” (USAF, 1995). This lean logistics master plan initially appeared soon after a RAND study of chronic DoD distribution problems.

In previous conflicts, users of the system habitually re-ordered the same part or supply over and over. Backlogs swelled at both CONUS and theater ports. Documentation about what had been shipped and received was, at best, spotty. Despite high-level attention and repetitive attempts to correct the problems, operations Desert Storm and Restore Hope show they still exist. In Desert Storm, over 25,000 containers shipped to theater had to be opened simply to determine contents and destination. Supplies were lost to the system, sometimes for months. Resupply of spare parts was ineffective. Equipment was deadlined, and some units received only minimal parts support. They were able to continue only because of what they had brought with them, because those quantities had been substantially increased above normal, and because of aggressive, dedicated, and labor-intensive efforts. (Moore, 1993)

The asset tracking procedures, upon which lean logistics depend, have broken down in every major conflict within the last 40 years. Logisticians have overcome the resultant lack of wartime asset visibility by relying on logistic mass and personnel. The criticality of distribution problems can be mitigated through the use of stockpiled assets (Moore, 1993). Also, the military establishment has been fortunate in the past to have had a significant percentage of its combat units not engaged in conflict. These reserve units have become an available source of spares and equipment. For instance, only 8 of 18 Army divisions fought in Desert Storm; every remaining division was tapped for spare assets. Current budgetary projections call for total Army strength to be reduced from 18 to 10 or fewer divisions (Moore, 1993). The logistic mass that Air Force logisticians have historically relied on to overcome asset visibility issues will be eliminated as lean logistics programs cut inventories and ongoing force reductions continue to eliminate wings. The Lean Logistics Master Plan recognizes the importance of automated cargo tracking in its "lessons learned:"

As transportation (rather than storage) becomes the prime contributor to our ability to deliver material on time, the importance of managing information about intransit assets and the status of movements becomes paramount. A tracking tool is necessary for LEAN LOGISTICS to succeed. Logistics information will become a principal commodity of the logistics system. As resources decline, the demand for tracking them becomes more of an issue. (USAF, 1995)

Despite the costs and difficulties associated with advancing asset visibility to the required level, the potential benefits are obviously enormous. From a cost savings standpoint, approximately 10 to 20 percent of all Air Force reparable assets are replaced annually, due to condemnations, modifications, or other compensations (Cohen, 1994). If just five percent of the F-16C inventory were replaced each year, annual charges would drop from \$63 million to \$23 million. If this program were implemented in each feasible weapon

system, total Air Force savings would amount to billions of dollars annually (Cohen, 1994).

For a lean logistics system to succeed and the resultant cost savings to be realized, assets must move rapidly and accurately in both peace and war. Without major modifications to current visibility systems, the viability of the lean logistics concept in a major regional conflict is questionable. The representative RF/ID system would offer a proven, highly reliable method of capturing the status and location of each asset as it moved through the military airlift system. Furthermore, at present prices the representative system or virtually any other commercially available RF/ID system could be acquired at a small fraction of the total annual savings projected for the lean logistics operations it would support.

## **Chapter Summary**

This chapter presented the information obtained through the research methodology in order to answer the investigative questions presented in Chapter I. Characteristics of commercial RF/ID systems were outlined, and a representative system was chosen. An estimate of system costs for acquisition and operation was provided, and cost avoidance issues of similar systems were discussed. Related wartime costs avoidance issues were presented, and the relationship between lean logistics, asset visibility, and RF/ID technology was explained. In the next chapter, research findings are discussed. Investigative questions are restated and addressed using information from this chapter and from the literature review for support. Recommendations for further research are offered.

## **V. CONCLUSIONS**

### **Chapter Overview**

This chapter answers the investigative questions presented in Chapter I. Each investigative question is restated in this chapter, with each followed by a discussion based on information obtained from the literature review and research methodology. Findings are summarized and recommendations for further research are presented.

### **Investigative Question One**

*What are the performance characteristics of existing RF systems?*

Many companies are currently producing RF/ID systems for use in commercial industry. A market study revealed that current systems are sub-divided into two major categories, consisting of those with passive transponders and those with active transponders. Passive transponders, or tags, utilize energy derived from a broadcast interrogation signal to power their communication transmissions. Active tags utilize an independent power source to provide energy for their transmissions. Virtually all currently available RF/ID systems offer a read/write capability, meaning that information contained within the tag may be altered repeatedly by the user. Available memory size ranges from as little as 26 bits per tag to as much as much as 2 megabytes. Similarly, operational transmission ranges from transponder to reader are from less than 2 meters to greater than 2000 feet. This range is primarily affected by the choice of active versus passive tags. Specifically, active tags offer ranges from between 200 feet and 2000 feet, while passive tags are generally limited to no more than 200 feet under the best of scenarios. Some passive tags are limited to ranges of less than 2 meters, although these shorter range tags are usually designed for specialized functions such as entry control and personnel tracking. The increased ranges of the active tag systems also results in the



disadvantage of a significantly shorter battery life. Whereas passive tags can be expected to operate in excess of ten years regardless of interrogation frequency, the more energy-dependent active transponders will begin to fail after less than a year under extremely frequent interrogation. Currently, the longest battery life available for an active transponder is approximately five years. This extended life is possible only with a minimum of interrogations over the period in question; more frequent interrogations will result in a noticeably decreased battery life. Federal Communication Commission Site Licenses are required for most passive systems, with requirements and limitations depending primarily on interrogator signal strength. Download times vary considerably among the major systems. Of those systems with an appreciable memory size designed into their tags, download times for standard information fall into categories of near-instantaneous, approximately two minutes, or close to 30 minutes.

## **Investigative Question Two**

*What are the costs of existing RF systems?*

Two primary cost profiles, the industry price ranges and the representative system cost breakdown, are used to depict this information.

Industry Price Ranges. Prices throughout the RF/ID industry appear to fall within discreet ranges dictated by the interrogation/response complexity. On a per unit basis, the smallest, shortest range tags vary in price from \$1 to \$20. Costs of longer range read-only backscatter tags range from \$10-\$30 per copy, while similar backscatter tags with read/write capability cost \$30-\$75 each. Active read/write tags cost from \$55-200, depending on options and memory size.

Prices for reader/interrogator units are also driven largely by system type and complexity. Very short range readers average approximately \$500, while active

read/write interrogators cost closer to \$2000 per copy. Backscatter read/write interrogators are the most expensive, costing up to \$8,000 each.

Costs of RF/ID hardware are moving steadily down as the systems receive broader acceptance and growing order volumes. Active tags are a possible exception to this trend, whose downward price momentum is not as noticeable due to these tags' requirement for relatively expensive batteries.

Representative System. Costs of the Intellitag IT 2000 provide a reasonable approximation of what the Department of Defense could expect to spend if an RF/ID system were acquired and implemented at the present time.

Acquisition. To establish a system that mirrors the most effective private industry applications, the 161,919 pallets in the Department of Defense inventory would have to be tagged with an RF transponder, at a total cost of \$7,934,031. Furthermore, approximately 1873 interrogator/readers would be required to ensure maximum coverage and provide the flexibility needed during two major regional contingencies. Purchase of the required number of readers would cost approximately \$7,488,000. As a subtotal, the direct outlay necessary to acquire these items is \$15,422,031.

System Installation and Development. Historical costs for installation and development of similar large scale systems show that initial hardware acquisition costs consistently run between 20% and 25% of the total initial investment. Using a conservative factor of 20%, the total initial investment should be \$77,110,155. This figure includes all activities required to create a viable system, consisting of acquisition, installation, integration, software development, and training.

Operation. The cost of ongoing operations primarily consists of software support and continuing training. Hardware operations costs are virtually non-existent. Annual operations costs for similar systems are normally 5%-10% of the initial system acquisition

cost. Conservatively, it would cost DoD approximately \$8 million per year to operate this system.

Maintenance. Maintenance expenses for the representative system's RF/ID tags are essentially zero. Tags contain no moving parts, are housed within a permanently sealed casing, and are ruggedized for use in all environments of the commercial transportation industry. Reader/interrogators experience a MTBF of 20,000 hours. When a failure does occur, the expected repair cost is a conservative value of 10% of the unit cost, or approximately \$400. Assuming all readers within AMC's network operate continuously, an annual hardware maintenance requirement of \$328,150 can be expected.

### **Investigative Question Three**

*How are existing RF systems being used in comparable commercial transportation industries?*

North American railroads lead the transportation industry in implementation of RF/ID systems. A mandatory standard for RF/ID tags within the railroad/intermodal market, sponsored by the American Association of Railroads, has dramatically increased industry investments in these systems. Currently, all major North American rail lines have made investments in RF/ID reader/interrogators, which are positioned at intervals along company track, at interfaces with contiguous track lines, and at more modern rail and intermodal terminals. This broad positioning and universal standard allow each fully equipped railroad to rapidly determine the location and status of assets located in its track network. At present, independent data services compile information supplied by each rail line to provide total asset visibility to commercial rail customers.

American President Lines and Matson Navigation both employ RF/ID systems to augment their intermodal container operations. These systems have permitted both shipping lines to automate their information processing systems, virtually eliminating the

need for manual record keeping and load manifesting. Container identification numbers, destinations, locations, and special indicators are all readily available to corporate operations and customer service personnel. In some instances, containers have been equipped with tags that monitor internal temperature, humidity, submersion, unusual accelerations, and unauthorized tampering. In addition to tagging all owned and leased containers, Matson Navigation has also installed transponders on all vehicle chassis operating within their system, including those of third-party users.

The Japanese airline, JAL, operates an active RF/ID system. Each JAL conformal pallet is equipped with a skirt-mounted active transponder unit, permitting total asset visibility on a real-time basis anywhere within the confines of the JAL system. The active transponders have virtually eliminated problems with even temporarily lost cargo, and allow JAL cargo handlers to perform instantaneous inventories of each container with handheld and fixed-base interrogation units. The availability of a broad spectrum of cargo information at a central database also facilitates advance loadplanning and rapid response aircraft diversions, which has resulted in a reduction in delays caused by unexpectedly high cargo volumes or unscheduled aircraft maintenance requirements.

#### **Investigative Question Four**

*How can existing RF technology be applied to 463L pallets to improve the current airlift system?*

By affixing a passive read/write tag to each of the 161,919 Department of Defense 463L pallets, and installing interrogator/readers throughout the AMC system, significant improvements to efficiency can be expected. Combined with a centrally located database or databases, these efficiency gains would result from nearly instantaneous information availability on the status and location of any given 463L pallet. This readily available information would reduce or eliminate many of the recurring logistical problems

experienced at aerial ports during recent conflicts. These consistently recurring problems include lost supplies, long requisition-to-receipt times, multiple requests for the same part, backlogs at CONUS and theater distribution nodes, and poor documentation of inventory and receipt. In addition, 463L hardware maintenance and accountability problems stemming from the current lack of individual pallet identification would be instantly rectified by implementing a RF system.

Lost Supplies. During every major conflict in the last 40 years, with the exception of Somalia, logisticians lost almost complete visibility of assets at aerial ports of embarkation. As a result, large quantities of high priority assets were shipped by surface after being arbitrarily packed into sea vans. Other assets remained unopened and anonymous at distribution centers and aerial ports. The commercial rail and intermodal container transportation industries have demonstrated that accurate asset tracking is possible at any node or line covered by adequate RF interrogator/readers.

Long Requisition to Receipt Times. Backlogs at cargo transfer nodes result in frequent mis-prioritization of outbound cargo. During the Gulf War, assets bumped from system flow while enroute to Saudi Arabia tended to remain in place until transportation teams compiled hand-written inventories of pallets and equipment remaining at their base. Commercial overnight parcel delivery companies have demonstrated the customer satisfaction levels that can be obtained through an accurate depiction of asset location at any given time. While overnight service is highly unlikely during a major regional conflict, a real-time summary of inbound assets would improve the ability of military customers to adjust asset dependent plans much as it does the civilian customers of Federal Express and UPS.

Multiple Requests for Same Part. Long requisition to receipt times combined with uncertainty of order status and the unreliability of the current pipeline result in rational customer coping behaviors, such as multiple requests for the same item. This

behavior reduces the future availability of assets to fill genuine requirements, and needlessly overburdens a wartime airlift system already operating at maximum capacity. Again, a real-time, accurate summary of inbound assets would prevent the recurrence of “elevator calling” coping behaviors consistently observed during past conflicts.

Backlogs at CONUS and Theater Distribution Nodes. Based on current studies of airlift requirements and capacities, cargo backlogs at CONUS and theater distribution nodes will continue to occur. However, the effects of these backlogs on overall system efficiency can be mitigated by maintaining accurate visibility of asset location throughout each node. As an example, one North American railroad reduced the average intermodal container off-load/on-load truck waiting time from one and a half hours to under twenty minutes using RF/ID readers to obtain specific information about inbound cargo.

Poor Documentation of Inventory and Receipt. During the Gulf War, as many as 25,000 of the 40,000 containers arriving in Saudi Arabia had to be opened and inventoried. The ultimate destination of these assets was frequently unknown, and consequently had to be determined by workers at transportation distribution nodes. These manpower intensive actions required enormous personnel resources that should have been available to expedite high priority cargo to final destinations. Transponders attached to each pallet virtually eliminate the possibility of assets arriving at a node without transportation and inventory information. In the civilian shipping and rail industries, arriving and departing containers are either routed through RF/ID interrogator/reader gates, or handled by RF/ID interrogator/reader-equipped MHE. As a result, all movement transactions are automatically recorded, independent of the human element.

### **Investigative Question Five**

*Do the expected improvements to asset visibility indicate that an RF system should be acquired at the present time?*

The decision to acquire a proven, commercially available RF/ID tracking system at the present time must be based on a subjective assessment of expected advantages weighed against estimated costs. Based on the experiences of the commercial transportation industry, operational cost savings would at minimum pay for the support and maintenance of the selected RF system. However, far more important than those savings are the customer support improvements that can be expected to result from implementation of such a cargo tracking system. Based on wartime asset visibility levels historically achieved in AMC, the resupply requirements dictated by lean logistics will certainly necessitate major technological and procedural improvements in cargo tracking in the near future. If these visibility levels can be achieved, lean logistics procedures can ultimately be expected to generate billions of dollars in annual cost savings. However, without the requisite automation of Air Force cargo tracking systems, history indicates that logisticians will continue to lose track of important assets in major conflicts. Of the currently available commercially proven technologies, passive RF/ID read/write systems appear to offer a promising solution at a moderate cost. Recommend additional study to determine the optimal commercially proven RF/ID system, software interface, and tracking database.

### **Summary of Findings**

The capabilities of currently available RF/ID systems offer significant potential improvements to Air Mobility Command's present asset visibility. The commercial transportation industry has demonstrated repeated successes using this technology in a variety of large scale operations, including railroads, deep water shipping concerns,

intermodal container carriers, and air cargo carriers. Projected costs to acquire and implement a representative RF/ID tracking system for the AMC/463L pallet system would be approximately \$77 million. Based on the experiences of the transportation industry when implementing similar systems, direct cost savings to core operations would approximately mirror the cost of RF/ID system upkeep. The chief benefits would be achieved in areas of customer service, especially during periods of high cargo volume. The levels of asset visibility possible through such a system would preclude the incidences of lost cargo common to all major conflicts within the last 40 years. Similarly, the improved asset visibility would reduce parts requisition to receipt times, reduce incidence of multiple requests for the same part, and help alleviate the backlogs present both at CONUS and theater distribution nodes. Also, automated record keeping and transaction processing features of similar systems employed by private industry virtually eliminate mistakes caused by poor documentation of cargo inventories and receipt. Based on increasing visibility requirements imposed by lean logistics procedures and inventory levels, some major system acquisition is inevitable. However, the capabilities of RF/ID systems are presently increasing at a rapid rate, while the costs of all but the active transponder systems continue to drop as higher sales volumes are experienced industry wide. The necessity of achieving near total asset visibility at the present time must be balanced against the more powerful RF/ID systems which will undoubtedly be available in the relatively near term, at a possibly lower cost. If a system were acquired at the present time, total activation costs could be expected to run approximately \$77 million, or about one-fourth the cost of a C-17 Globemaster III.

### **Recommendations for Further Research**

This thesis focused on researching costs and capabilities of commercially available RF/ID tracking systems, with an emphasis on those systems that have demonstrated



successes within the commercial transportation industry. During the course of this research effort, questions have surfaced that may offer opportunities for additional study.

Recommend a narrowed research focus, concentrating on one major commercial transportation corporation that has successfully implemented an RF/ID system. A broad spectrum of transportation corporations and modes has been studied in this research, which provided valuable insight into industry trends and standards. By narrowing the research to one large corporation, researchers may identify implementation hurdles and opportunities which could be applied to future Air Force RF/ID programs.

Recommend a study of possibilities for tagging all Air Force rolling stock. The scope of this research was strictly limited to tagging DoD 463L pallets. Installing RF/ID transponders on all Air Force wheeled equipment would present challenges of standardization perhaps not yet experienced by the commercial transportation industry. However, if a 463L RF/ID tracking system were successfully implemented, the logical next step would be to tag all remaining mobile Air Force assets.

Recommend a study of the most successful tracking software used in conjunction with large scale RF/ID systems in private industry. While many RF/ID vendors offer applications software interfaces for their systems, large corporations are normally faced with independently developing many of the databases and communications links required to complete their respective systems. Studying operational industry successes may provide insights that will aid in developing the required Air Force specific software.

## References

- AFMC. *Radio Frequency Identification (RFID): Market Study* (Draft). Wright-Patterson AFB OH, 6 April 1995.
- Amtech Corporation. "Management's Discussion and Analysis of Financial Condition and Results of Operations," *Annual Report*. Dallas TX (January 1995).
- Blanchard, Benjamin S. *Logistics Engineering and Management*. Englewood Cliffs: Prentice Hall, 1992.
- Bonney, Joseph. "Conrail, UP Add Stacktrain Terminals," *American Shipper*, 37: 54 (January 1995).
- Bressel, William. HQAMC XPDI, Scott AFB IL. Telephone interview. 24 February 1995.
- Brown, Randall. Vice-President, Marketing, Amtech Corporation, Dallas TX. Telephone interviews. June - August 1995.
- Church, V. M. "Technology takes the toll," *Popular Science*: 78-80 (July 1992).
- Cohen, I.K. and others. *Lean Logistics: A More Responsive, Robust, and Affordable System* (Draft). RAND Corporation, DRR-630-1-AF, Santa Monica CA, 1994.
- Coyle, John J. and others. *Transportation*. St. Paul MN: West Publishing Company, 1994.
- Department of the Air Force. *Air Mobility Command Intransit Visibility: Providing Intransit Visibility for Air Movement*. Scott AFB: HQ AMC, 1994.
- Department of the Air Force. *Air Force Doctrine* [Draft], AFDD-40, 10 May 1994.
- Estey, Paul. *AIT Benefits* [Draft], Volpe National Transportation Systems Center, Cambridge, July 1993.
- Fletcher, Peter. "Standards Issues are Next Hurdle," *Electronics*: 7 (February 1993).
- Fogleman, Ronald R., Commander in Chief, Air Mobility Command. *Air Force Consideration of Commercial Tracking Systems [Answer to Open Forum Question]*. Air Force Association Meeting, Washington, December 1993.

Gibson, Robert. Air Transportation Equipment Manager, AMC/DOZE, Scott AFB IL. Telephone interviews. July - August 1995.

Gosch, John. "Philips' Premid features read/write capability." *Electronics*: 7 (February 1993).

----- "Siemens RF-ID Modules Monitor Car Plant." *Electronics*: 7 (February 1993).

Government Accounting Office. Operation Desert Storm: Lack of Accountability Over Materiel During Redeployment. Report NSIAD-92-258. Washington: Government Printing Office, September 1994.

Gregorcsek, Steve. Chief, ITV cell, HQAMC/TACC. Telephone interview, 24 February 1995.

Herst, Eric R. "AEI Adds Accuracy to JIT Logistics," *Global Trade & Transportation*, 11: 58 (November, 1993).

Horngren, Charles T., George Foster and Srikant M. Datar. *Cost Accounting: A Managerial Emphasis*. Englewood Cliffs: Prentice Hall, 1994.

HQ AMC. *Providing Intransit Visibility*. Procedural Changes Document. Scott AFB IL, 27 October 1994.

Humphries, Rosemary. 463L Inventory Manager, WR-ALC/LVDV, Warner-Robbins AFB GA. Telephone interview. 20 July 1995.

Joint Logistic Review Board. *Logistic Support in the Vietnam Era: A Summary Assessment with Major Findings and Recommendations*. Washington: Office of the Secretary of Defense, 1 March 1970.

Klapperich, Ronald. Intermodal Container Tracking Services Manager, CLM division, Klein-Schmeidt Corporation, Deerfield IL. Telephone interview. 22 June 1995.

Kloeckner, Del. Budget Analyst, AMC/FMBT, Scott AFB IL. Telephone interview. 1 August 1995.

Landt, Jerry. Vice-President, Research and Development, Amtech Corporation, Albuquerque NM. Telephone interview. 28 July 1995.

Larberg, Gary W. "The Airlift Clearance Authority: Providing Shipper Service at the Aerial Port," *Air Force Journal of Logistics*, 16: 25-27 (Winter 1992).

- Lorraine, Eric C. and Michael E. Michno. *Logistics Control Facility: A Normative Model of Total Asset Visibility in the Air Force Logistics System*. MS thesis AFIT/GLM/LAL/94S-25. School of Logistics and Acquisition Management, Air Force Institute of Technology (AETC), Wright-Patterson AFB OH, September 1994 (AD-A285003).
- Moore, N.Y. and others. *Material Distribution: Improving Support to Army Operations in Peace and War*. Rand Corporation, DDR-440-A, Santa Monica CA, 1993.
- Mueller, George E., Robert F. Rozycki, and Click D. Smith, Jr. *Improving Cargo Visibility in the Joint Deployment System*. Bethesda: Logistics Management Institute, August 1986.
- Patrick, Mike. Emery Worldwide Supervisor of Ramp Operations, Dayton Hub. Dayton OH. Personal interview. 24-25 Feb 95.
- "Pentagon Reports to Capitol Hill on Cheaper C-17 Price Tag," *Defense Daily News*, 187: 424 (21 June 1995).
- Roos, John G. "Force Projection Logistics: Total Asset Visibility from Factory to Foxhole," *Armed Forces Journal International*, 10: 29-32 (February, 1994).
- TACC. MAIRS C-141 Mission Summary. Scott AFB IL. January - March 1992.
- Taylor, David, and others. *Agile Sword 1994: Exercise Reconstruction and MITLA Operational Evaluation*. CNA Field Memorandum, 2 February 1995.
- TRESP. *Economic Analysis for Total Asset Visibility (TAV)*. DAAK-70-92-C-0077. 1993.
- USAF Baseline Lean Logistics Master Plan and Road Map; Version 3.0, HQ USAF/LGM-2, 31 January 1995.
- US TRANSCOM. *Requirements Document for Automatic Identification Technology in Support of the Defense Transportation System* (Draft). Service/Agency AIT Workgroup Requirements Document, 1994.
- U.S. Department of Transportation. *In-Transit Visibility*. Cambridge: Volpe National Transportation Systems Center, February 1991.
- *Future-Europe, Automated Identification Technology, Material Visibility Program, Implementation Plan, Phase II*. Cambridge: Volpe National Transportation Systems Center, May 1993.

### Vita

Captain Gary A. Gross was born on 5 June 1968 in Washington, D.C. He graduated from West Potomac High School in 1986 and entered the United States Air Force Academy later that year. Captain Gross graduated on 30 May 1990 with a Bachelor of Science in Management, and was commissioned that same day with orders to Cannon AFB in Clovis, New Mexico. He arrived at Cannon AFB in August 1990, the same day Operation Desert Shield began. Captain Gross served as a logistics officer in the Resource Plans Division until implementation of the objective wing structure. Following this transition, he served as a logistics officer in the Logistics Plans Flight. In May 1994, Captain Gross entered the Graduate Logistics Management program, Graduate School of Logistics and Acquisition Management, AFIT. Captain Gross has a follow-on assignment to the F-22 System Program Office, Wright-Patterson AFB, Ohio.

Permanent address: 2631 Childs Lane

Alexandria, VA 22308

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</small>				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE September 1995	3. REPORT TYPE AND DATES COVERED Master's Thesis		
4. TITLE AND SUBTITLE TRACKING AIR FORCE PALLETS USING RFID TECHNOLOGY: A CONCEPT STUDY		5. FUNDING NUMBERS		
6. AUTHOR(S) Gary A. Gross, Captain, USAF				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)  Air Force Institute of Technology, WPAFB OH 45433-7765		8. PERFORMING ORGANIZATION REPORT NUMBER  AFIT/GLM/LAL/95S-6		
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)  AFSAA/SAGM Washington DC 20330		10. SPONSORING / MONITORING AGENCY REPORT NUMBER		
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT  Approved for public release; distribution unlimited		12b. DISTRIBUTION CODE		
13. ABSTRACT (Maximum 200 words)  The lack of asset visibility experienced at Aerial Ports of Embarkation (APOEs) during Operation Desert Storm is a phenomenon that has occurred in every major conflict for the last 40 years. The costs associated with this lack of control directly relate to the combat readiness and capability of supported units. This study examined the possibility of installing a Radio Frequency Identification (RF/ID) system to track Department of Defense 463L pallets worldwide. Performance characteristics of commercially available RF/ID systems were summarized, and a conceptual Air Mobility Command (AMC) tracking system was presented. For purposes of concept study, Amtech Corporation's Intellitag RT 2000 system was selected as the representative system. Costs to acquire, implement, and maintain the representative system approach \$77,000,000, based on AMC requirements and historical costs of similar large scale commercial systems. Projected benefits of RF/ID implementation are discussed in terms of lean logistics, estimated wartime cost-avoidance, and operational tests of similar systems.				
14. SUBJECT TERMS Logistics, Air Force, Cargo Tracking, Total Asset Visibility, Intransit Visibility, Radio Frequency Identification, RFID, 463L Pallets, Automated Information Technology.			15. NUMBER OF PAGES 68	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL	